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ABSTRACT

This paper describes two experiments conducted to replicate the reported findings (Entus, 1975) that infants demonstrate a right ear advantage in the perception of dichotically presented syllables. Using the non-nutritive sucking paradigm, 48 infants 1-3 months of age were presented with verbal stimuli contingent upon criterion level sucking. Following habituation to a stimulus pair, the sound was changed in one ear and the rate of recovery in criterion sucking was recorded. After a short break, the same procedure was repeated with the shift in the stimulus pair occurring in the opposite ear. In both replication attempts, stimulus material, response criteria and equipment involved in recording response measures were identical to those used by Entus. However, the following control measures were introduced: (1) an adjustable mechanical arm to hold the nipple-transducer; (2) a double blind procedure, rendering the experimenter blind to the order of stimulus combinations; (3) a divider screen, separating the experimenter from the subject in order to eliminate possible biasing interactions; (4) the level of criterion sucking was readjusted and reduced (Experiment 1) in order to ensure conditioning of the sucking response. Analysis of variance on the recovery scores was performed to determine the effects of ears, minutes, sex and order of stimulus change. In both experiments there were no significant differences in the recovery scores between ears. These results are discussed in terms of the possible effects of experimenter bias and lack of adequate controls that could have contributed to the findings reported by Entus. (Author/MS)

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CEREBRAL ASYMMETRY IN INFANTS*

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Introduction

It is now well established, on the basis of a wide variety of clinical and experimental investigations, that the two cerebral hemispheres of the adult human brain are specialized for different functions (e.g., Dimond & Beaumont, 1974). However, the course of development of this functional asymmetry is a more controversial issue and, in particular, there is disagreement as to whether it is present at birth, or whether it develops gradually over the early years of life.

The most widely held view of the development of cerebral asymmetry, expounded by Lenneberg (1967), states that either hemisphere is capable of providing a neural substrate for the effective development of speech and language in early life. However, this equipotentiality decreases as the child nears puberty. Thus children who suffer severe unilateral cerebral damage prior to the age of 12 may subsequently develop more or less normal language functions, despite some temporary impairment, regardless of the side of the lesion (Basser, 1962; Reed and Reitan, 1969; Dennis & Kohn, 1975).

Recently, a number of investigators have challenged the view that hemispheric asymmetry develops during life, and have suggested instead that it may be present at or before birth. Some of the anatomical asymmetries demonstrated in the adult brain have also been measured in the brains of infants and neonates (Witelson and Pallie, 1973; Wada, Clarke, and Hamm, 1975). Asymmetries in averaged evoked responses (Molfese, Freeman and

Palermo, 1975; Davis and Wada, 1977) and EEG activity (Crowell, Kapuniai, Jones & Nakagawa, 1973) have been reported during auditory and visual stimulation in infants. Further, heart rate deceleration in response to the introduction of a contrast stimulus has been found to be ear dependent during dichotic presentation of speech sounds (Glanville, Best and Levenson, 1977). Thus recovery of cardiac orienting was greater when a novel speech stimulus was introduced to the right rather than the left ear and when a new music stimulus was presented to the left rather than the right ear.

However, only one investigation has reported functional cerebral asymmetry using a behavioral response. Combining the use of the non-nutritive sucking paradigm (Siqueland and deLucia, 1969) with the dichotic listening technique, Entus (1975) reported that young infants demonstrate a right-ear advantage in the perception of speech sounds and a left-ear superiority in the processing of non-verbal musical sounds.

The studies reported here represent two attempts to replicate Entus's finding of a right-ear advantage for the perception of elementary speech sounds. Except for the addition of several control measures ensuring against experimenter bias, the two replication studies involved the use of the same procedures, stimuli and apparatus as those employed by Entus.

METHODS

Subjects

All subjects were recruited from local hospitals or birth

announcements in newspapers. A total of 78 infants were brought to the laboratory for testing. Thirty subjects were excluded from the sample on the basis of: 1) persistent crying or fussing either during habituation or recovery; 2) failure to emit any sucks during the first minute after the decrement criterion; 3) failure to emit at least 15 sucks during the one minute baseline period; 4) failure to complete both blocks of the test session and 5) deep sleep.

In each experiment, the subjects were 24 healthy, full term infants divided equally between the two sexes. The mean age of the subjects in experiment I was 7 weeks 5 days old, with a range from 4 to 13.2 weeks. In experiment II the mean age was 9 weeks 3 days with a range from 4 to 14.5 weeks. Parents of infants were requested to fill out a questionnaire giving details of handedness history in the family.

Stimuli

The stimuli used in both experiments consisted of the four consonant-vowel syllables /ma/, /ba/, /da/ and /ga/ spoken by an adult male voice. Using a PDP-11 computer, three dichotic tapes were made, each consisting of 5000 identical renditions of each of the following stimulus pairs: ma-ba; da-ba, and da-ga. The stimulus duration was 500 msec. with a 500 msec. inter stimulus interval. The dichotic pairs were recorded at identical intensity levels and were presented to the subjects at an intensity level of 75 db (measured by Stadler Sound-level Meter, weighted at A).

Apparatus

Two testing rooms separated by a one way glass were used: one for the equipment and operator, the other for the experimenter and the subject. The apparatus consisted of a blind nipple (Evenflow) attached to a Statham (Model P23AA) physiological pressure transducer. Pressure changes on the nipple transducer were relayed and received by the DC preamplifier of a 4 channel Grass Polygraph (Model 7) which yielded a graphic record of sucking. Pen deflections beyond a mechanically set criterion level on the polygraph activated a Sony quadrophonic tape recorder which presented the dichotic stimuli to the infants. Two automatic counters (Simpsons, DC, 12.5V) recorded criterion sucks per minute. A pair of RCA voltmeters (Model WV517A) were attached to the amplifier of the tape recorder and were relayed to the AC preamplifiers of the polygraph, which provided a graphic record of stimulus presentations.

Procedure

Infants were always awake at the beginning of the testing session. Testing proceeded uninterrupted despite apparent changes of state provided that the sucking response was continued. Each infant was placed in a semi-reclining seat and wore stereophonic headphones (Maico, Model 5488).

First, a baseline rate of sucking was established while the infant sucked the nipple without receiving any sounds. For about the first 30 seconds of free sucking, adjustments were made in the criterion sucking pressure necessary to activate

the polygraph. This was followed by a 1 minute period during which a baseline count was made. In experiment I the criterion was set fairly low so that the baseline would lie between 40 and 70 sucks per minute. In experiment II, for reasons given below, the criterion was altered so that the baseline rate was between 20 and 40 sucks per minute.

Following baseline recording, a dichotic pair of sounds was presented each time the infant sucked with a pressure exceeding the criterion. Sucking rate was recorded minute by minute. When the contingency was introduced, sucking rate typically increased, but with repeated presentation of the same dichotic pair the rate eventually decreased, or habituated. A habituation criterion was set at two thirds of the maximum rate recorded during any 1 minute period. When the rate fell below this criterion for two consecutive minutes, the sound in one ear was changed. The other ear continued to receive the same sound. The new pair was presented for a further 5 minutes, and the post-change rate recorded minute by minute. Sucking rate typically increased, or recovered, during this period. After a 10 minute break, the habituation and recovery phases were repeated with the stimulus change occurring in the other ear. Half of the subjects received the first change in the left ear, while the other half received the first change in the right ear. Within each group, the headphone positions were also counterbalanced between subjects.

Figure 1

The following modifications were made in the procedure used by Entus in order to ensure against experimenter bias. In the Entus study, the rubber nipple was held by the experimenter and re-inserted in the infant's mouth whenever it was ejected. Since the experimenter was not completely blind to the order of stimulus conditions (i.e. which ear received the shift in sound stimuli) she could have inadvertently influenced the subject's response. To control for these factors, a mechanical arm was used in the present experiments to hold the nipple transducer. Furthermore, a double blind procedure was introduced whereby the counterbalanced order of stimulus combinations, which was achieved in Entus's study by reversing the headphones between subjects, was regulated from the adjoining testing room. Thus the experimenter with the infant had no knowledge of either the testing phase or the order of stimulus combinations. Lastly, a divider screen was placed between the experimenter and the subject to eliminate possible biasing interactions.

Further modifications were made in experiment II. As noted above, the criterion sucking level was adjusted so that the baseline sucking rate was between 20 and 40 sucks per minute; in addition, the first two minutes of contingent sucking did not count toward recording a maximum sucking rate for the purposes of defining a criterion of habituation. These changes were made in an attempt to improve the quality of conditioning. Conditioning of the sucking response is best achieved when criterion sucking is adjusted strictly, thus allowing a sizeable increase

in contingent sucking during the habituation phase (Trehub & Chang, in press). In Entus's study and in experiment I, the lenient sucking criterion resulted in high rates of contingent sucking; the maximum ranged from 58 to 134 in Entus's study and from 48 to 124 in experiment I. These rates are rather high, given that two criterion sucks per second produced continuous activation of the sound. Thus at least some of the infants in these experiments sucked at too high a rate to receive a dichotic pair for every suck. With the modifications introduced in experiment II, the maximum achieved during contingent sucking ranged from 17 to 65 sucks per minute.

RESULTS

Recovery of sucking rate was analyzed as a function of the ear which received a stimulus change. On the assumption that recovery of sucking reflects the ability of the infant to discriminate a change in the stimulus condition, a greater recovery following a change in the right ear would suggest that the left hemisphere is the more specialized in making such discriminations (Kimura, 1961).

The data for each subject consisted of the number of criterion sucks per minute recorded over successive minutes. In order to avoid the biasing influences of atypical sucking rates, percentage scores based on each subject's maximum predecrement sucking rate was calculated. Mean sucking scores during the five minutes before and after the decrement criterion for experiments I and II are shown in figures 2 and 3.

Insert Figures 2 and 3 about here

Figures 4 and 5 compare the above mean scores to those reported by Entus.

Insert Figures 4 and 5 about here

Analysis of variance on percentage scores of the last five minutes prior to decrement criterion (habituation) revealed no significant differences depending on which ear was receive a novel stimulus.

Analysis of variance on the post-decrement (recovery) percentage scores were performed to determine the effects of ears, minutes, sex and order of stimulus change (left-right shift vs. right-left shift). In both experiments, there were no significant differences in the recovery scores between ears (Experiment I, $F(1,20) = 1.32$; Experiment II, $F(1,20) = 0.47$). A distribution of the pattern of ear asymmetry indicated by subjects in both experiments is shown in figure 6.

Insert Figure 6 about here

The only significant effect found was that of sex in experiment II. Mean sucking rate during recovery phase was significantly higher in male infants (mean for male subjects = 60.37, female subjects = 48.12), $F(1,20)=6.40$, $p < .01$. None of the remaining

main effects nor any interactions with ears or other factors were found to reach conventional levels of significance.

A separate analysis of variance was performed on the post-decrement scores of 18 infants (selected from the sample of Experiment II) who were born of right handed parents with no family history of left handedness. All of these infants were fully awake during the two blocks of testing conditions. Main factors included in this analysis were those of ears, sex and order of stimulus change. Once again the only significant effect found was that of sex, indicating higher recovery of sucking rate in male infants (mean for male subjects = 58.41, female subjects = 41.75).

In order to determine whether the introduction of a stimulus shift irrespective of ears, had significantly affected the recovery of sucking response, two separate analyses of variance were performed on the last pre- and the first post-decrement percentage scores of the two experiments. Results of these analyses indicated that sucking rate in the first minute of post-decrement period was significantly higher compared to the last minute of pre-decrement phase.

Insert Table I about here

In Experiment I, mean recovery of sucking for right ear was 59.8 ($F(1,23) = 4.98.5$, $p < 0.05$). Mean recovery of sucking for left ear was 63.62 ($F(1,23) = 15.59$, $p < 0.0006$). In Experiment II, mean recovery of sucking for right ear was 58.95 ($F(1,23) = 7.77$,

$p < 0.01$) and 62.14 for left ear ($F(1,23) = 6.27$, $p < 0.01$) for the left ear.

DISCUSSION

These results do not confirm Entus' (1975) finding that infants demonstrate hemispheric specialization in the perception of dichotic speech sounds. The fact that significant recovery of the sucking response was demonstrated after the introduction of a new contrast syllable, is consistent with earlier reports (Eimas, Siqueland, Jusczyk and Vigorito, 1971; Moffitt, 1971; Trehub and Rabinovitch, 1972) that infants discriminate consonant-vowel contrasts. However, the present results suggest that this discrimination can be made equally effectively by either the left or the right ear.

Failure to replicate Entus' result may be due to the modified procedure. It is possible, for instance, that the use of a mechanical arm in place of the experimenter to hold the nipple in the infant's mouth may have "depersonalized" the testing situation to the point that the infant did not interpret the sounds as related to human speech. Alternatively, Entus' result may have been due to unconscious experimenter bias, which would have been eliminated in the present experiments. If the latter interpretation is correct, our results are amenable to two possible conclusions: either a) the technique is insufficiently sensitive to demonstrate the functional asymmetry of the infant brain, or b) there is no significant difference between the capacity of the left and right cerebral hemispheres to discriminate speech sounds at this age.

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Notes

1. The authors acknowledge the use of the computer-based laboratory of the McGill University Department of Psychology, supported by the National Research Council of Canada, the F.C.A.C. program of the Quebec Ministry of Education, and the McGill University Graduate Faculty.

2. The speech stimuli were recorded in a broadcast studio on an Ampex Mono tape-recorder (Model 351) with a Gates console, full track reel-to-reel at 7½ in. per sec.

3. Two computer programs were used in preparing the dichotic tapes. The first was used to transfer the original stimuli onto Dec tape and to determine that the duration of each was exactly 500 msec. The second was used to line up the onset of each dichotic pair and record it on a Quadrasonic Sony tape recorder at 7½ in. per sec.

Figure Legends

Figure I. Schematic representation of the experimental procedure.

Figure II. Mean number of sucks per minute, expressed as a percentage of the maximum pre-decrement sucking rate, for 5 minutes before and after the decrement criterion in Experiment I.

Figure III. Mean number of sucks per minute, expressed as a percentage of the maximum pre-decrement sucking rate, for 5 minutes before and after the decrement criterion in Experiment II.

Figure IV. Mean number of sucks per minute for 5 minutes before and after the decrement criterion in Experiment I, superimposed on the results reported by Entus.

Figure V. Mean number of sucks per minute for 5 minutes before and after the decrement criterion in Experiment II, superimposed on the results reported by Entus.

Figure VI. Proportion of subjects demonstrating ear asymmetry in the two experiments.

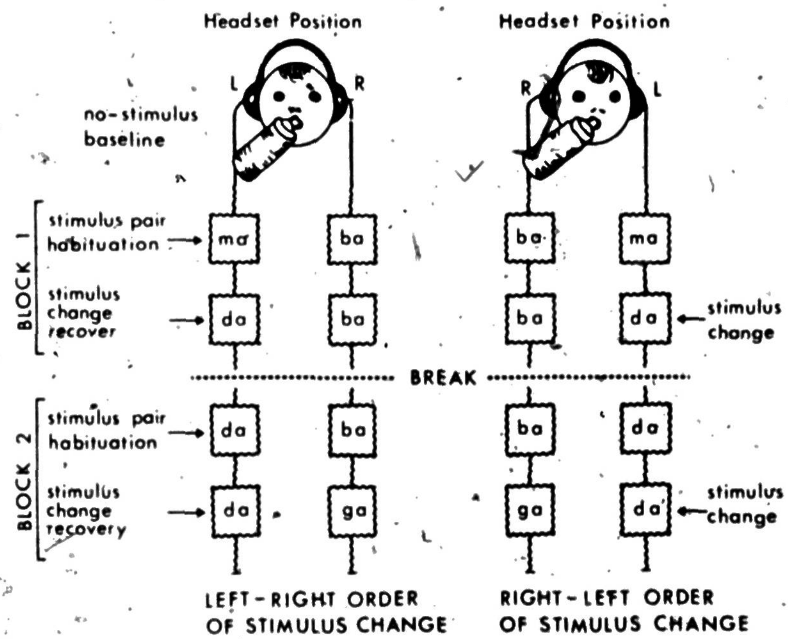
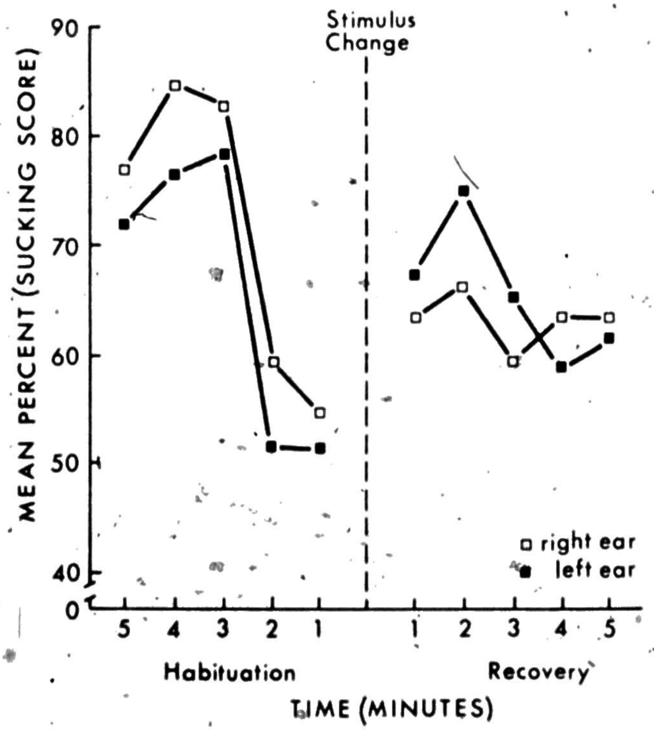
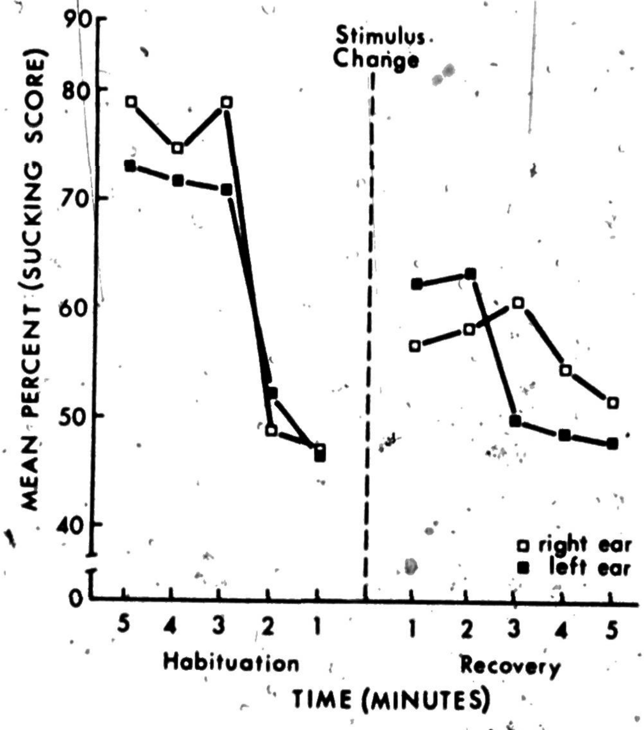

Headset Position
Headset Position
L
R
R
L
no-stimulus baseline
BLOCK 1
stimulus pair habituation
stimulus change recover
ma
ba
da
ba
ba
ma
ba
da
stimulus change
BREAK
BLOCK 2
stimulus pair habituation
stimulus change recovery
da
ba
da
ga
ba
da
ga
da'
stimulus change
LEFT-RIGHT ORDER OF STIMULUS CHANGE
RIGHT-LEFT ORDER OF STIMULUS CHANGE

FIGURE **1**



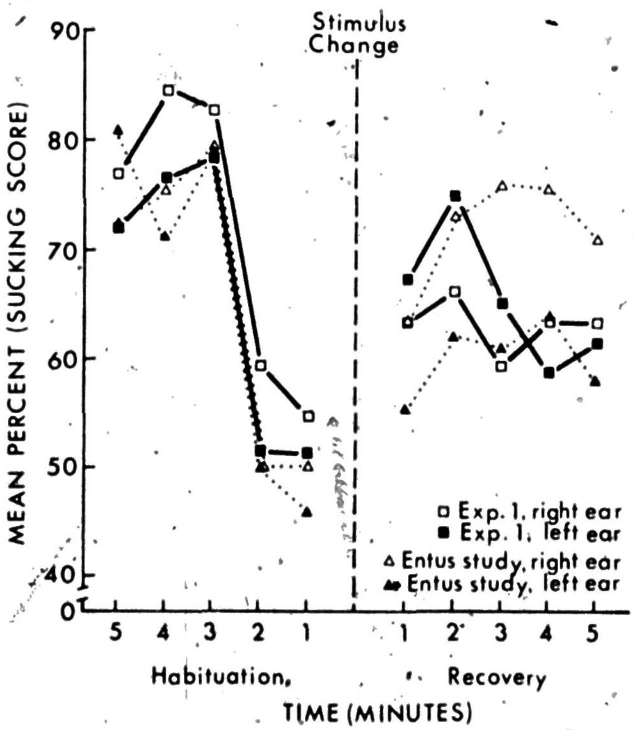
Stimulus Change
90
80
70
60
50
40
0
MEAN PERCENT (SUCKING SCORE)
5
4
3
2
1
1
2
3
4
5
Habituation
Recovery
TIME (MINUTES)
□ right ear
■ left ear

FIGURE **2**



90
80
70
60
50
40
0
MEAN PERCENT (SUCKING SCORE)
Stimulus
Change
right ear
left ear
5
4
3
2
1
1
2
3
4
5
Habituation
Recovery
TIME (MINUTES)

FIGURE 3



Stimulus Change
90
80
70
60
50
40
0
MEAN PERCENT (SUCKING SCORE)
□ Exp. 1, right ear
■ Exp. 1, left ear
△ Entus study, right ear
▲ Entus study, left ear
5
4
3
2
1
1
2
3
4
5
Habituation
Recovery
TIME (MINUTES)

FIGURE 4

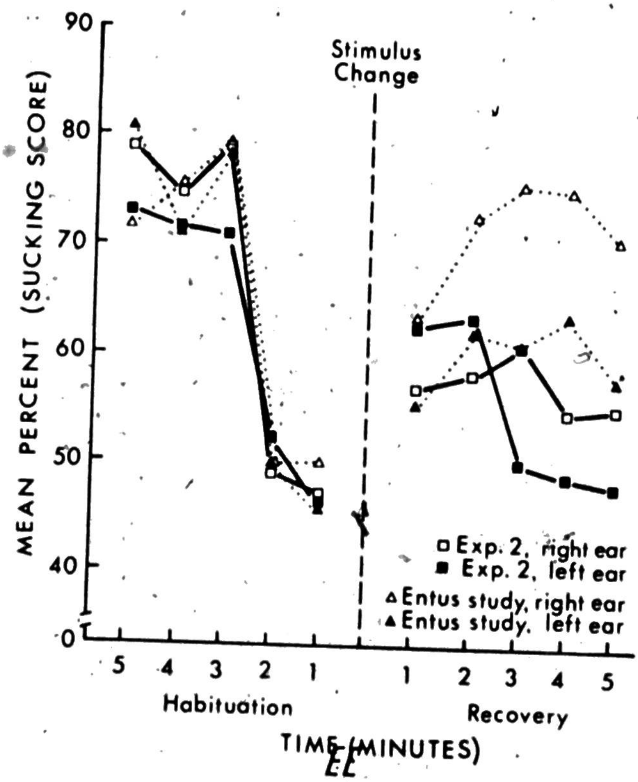

Stimulus
Change
90
80
70
60
50
40
0
MEAN PERCENT (SUCKING SCORE)
□ Exp. 2, right ear
■ Exp. 2, left ear
△ Entus study, right ear
▲ Entus study, left ear
5
4
3
2
1
1
2
3
4
5
Habituation
Recovery
TIME (MINUTES)

FIGURE 5

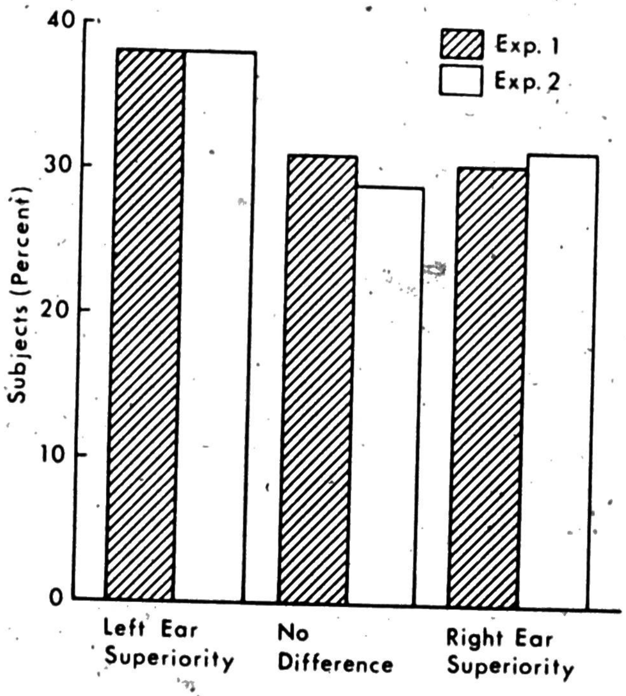

Exp. 1
Exp. 2
Subjects (Percent)
40
30
20
10
0
Left Ear Superiority
No Difference
Right Ear Superiority

FIGURE 6

SIGNIFICANT ANOVA EFFECTS

Last Pre and First Post-Decrement Sucking Scores

Experiment	Recovery	Mean (%)	F	df	P
I	Left Ear	63.62	15.59	1/23	0.006
	Right Ear	59.80	4.98	1/23	0.05
II	Left Ear	62.14	6.27	1/23	0.01
	Right Ear	58.95	7.77	1/23	0.01

TABLE 1